The Recent Eruption of Ngauruhoe

By M. H. BATTEY, Geologist.

Abstract.

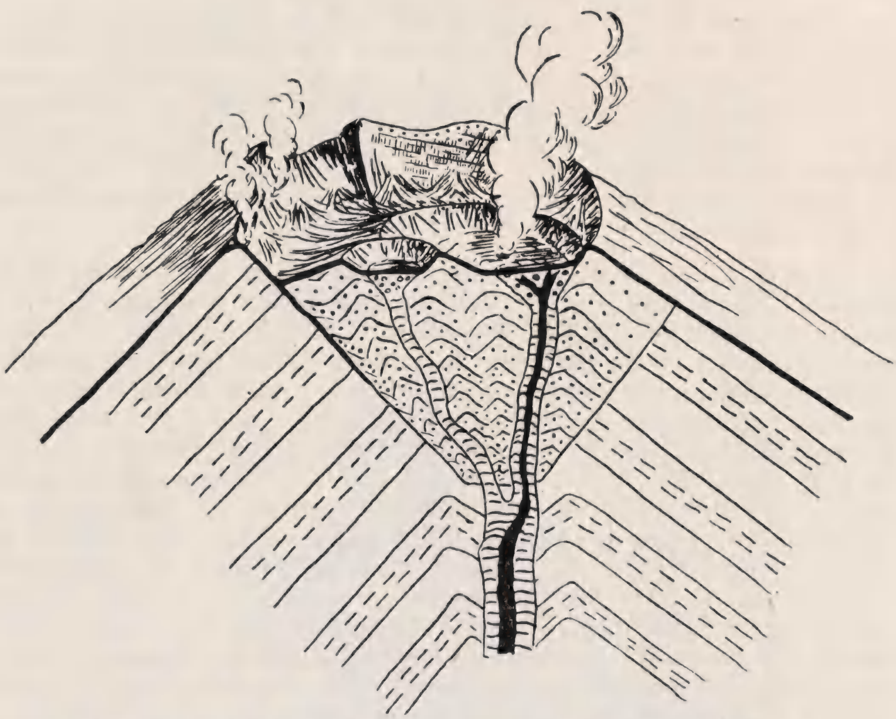
An eruption of the andesite volcano Ngauruhoe took place during February, 1949. A number of hot avalanches were discharged in the early stages; this phase was succeeded by the emission of a lava flow 2,000 yards long, and the eruption concluded with a period of explosive ash-production such as has formed the only manifestation of activity previously observed.

This paper describes the early part of the eruption and, in particular, the phenomena connected with the lava flow, which was the first to be observed in New Zealand. A map of the flow is presented and the petrography of the lava is briefly discussed.

Introduction. Ngauruhoe is a symmetrical volcanic cone built to a height of 7,500 feet upon the southern flank of the older complex volcano Tongariro (6,458ft.), which rises, alongside the volcano Ruapehu (9,175ft.), above the central plateau of the North Island of New Zealand.

Ngauruhoe has shown intermittent activity, with the emission of clouds of ash, ever since it has been under observation. Bidwell (1841), the first European to climb the mountain, made his ascent during a phase of mild explosive activity in 1839. Thomson (1926, pp. 358-9) has given a summary of the recorded activity up to 1926; since then the volcano has been reported active some half-dozen times, the latest manifestation, prior to the eruption of February, 1949, being a vigorous explosive outburst in the first week of May, 1948.

It would seem that there has been little fundamental change in the crater of Ngauruhoe, at least since the year 1887. The main crater is a roughly circular depression somewhat more than a quarter of a mile across, bordered on the south and east by steep cliffs which are probably rather more than 300 feet high at their highest point, on the south-east. On the north and west the rim is very much lower, and at its lowest point it rises but little above the level of the general crater floor (cf. sketches by Hill, 1891a, Marshall, 1908, and plate 71, fig. 1, accompanying this paper). Within this crater, towards its western lip, two centres of activity have apparently persisted for many years. Hill (1891a, pl. XLV) in his sketch of the crater in 1890 depicts these two sub-craters and remarks (p. 611) that they were clearly defined and quite separate, while Cussen (1891) shows two sub-craters, likewise, on his map. Marshall (1908, p. 103), while agreeing with Hill's description (in which two sub-craters are mentioned), asserts positively that the more southerly of Cussen's two sub-craters was not there in January, 1891. In 1893, however, according to Marshall, an explosion crater had appeared in the central part of the main crater, more or less in the position of Cussen's southern sub-crater, and it subsequently became enlarged until, by 1906, its west wall was coincident with that of the main crater. From this time forward the two sub-craters have persisted, one in the north-north-west and the other in the western part of the main crater. Minor changes, such as the building of small cones about the vents and the partial filling and coring out of these sub-craters, have taken place from time to time. Fumaroles are marked at the foot of the high cliffs on the north-east side of the main crater on Turner's map (1911), while Hill (1891a, p. 611) records the issue of steam from the walls of the major crater over most of the face exposed. (A trace of steam can be seen above the N.E. cliffs in plate 73, fig. 2.) Fumaroles have also long existed on the north-north-western exterior slopes of the cone. Hill, 1891, pp. 60-2, mentions them, and Turner (1908) estimates that they are roughly 150 feet below the crater rim. The activity at these places, so far from the main vent, when taken in conjunction with the fact, first noted by Hill (1891b), that "on the sides of the cone where the lip of the crater is lowest there is hardly any trace of lava; ashes, cinders and scoria prevail . . ." suggests that at some time the north-west part of the summit of Ngauruhoe has been destroyed by explosion or collapse, and that a secondary cone has been built up within the resulting depression, about the historic centre of activity (see Text fig. 1). The north-west slopes of this secondary cone are confluent with those of the main volcano, the junction of old and new structures affording a path to the surface for some of the volcanic exhalations, so that its surface trace is marked by the fumaroles on the outer slopes of the cone and below the north-eastern cliffs of the main crater rim.



Text fig. 1. Suggested structure of the upper part of Ngauruhoe cone.

Red hot lava was reported in the western sub-crater in January, 1911 (Turner, 1911, p. 35; Marshall, 1934, p. 4), and again in March, 1928 (Grange, 1928, p. 146), and fairly vigorous explosive activity took place on the second occasion.

The lava-front at 9 a.m. on February 12. The flow stopped just before reaching the flat. The edge of the avalanche debris-fan appears in the right foreground.

Photo: M. H. Battey.

The steep front of the advancing flow on February 11 was about 20ft. high.

Photo: R. C. Cooper.

It has been asserted that a lava-flow was extruded from the crater in 1869 or 1870 (Hector, 1887, pp. 463-4). The facts are uncertain, but two lava-flows certainly of very recent date extend to the foot of the cone on its north-north-west flank (Hill, 1891b, p. 165), while another has spread out towards the floor of the South Crater of Tongariro, at the northern base of Ngauruhoe cone (Thomas, 1888, p. 341; Grange, 1928, fig. 1). Hill (1891a, p. 609) maintains that the one that he describes was noted by Bidwill in 1939, and (p. 612) that no lava was erupted in 1869.

The Eruption of 1949. Quite abruptly, at about 1.30 a.m. on Wednesday, February 9, 1949, Ngauruhoe began a new phase of violent activity.

On the previous day two climbers, Messrs. R. H. Bates and T. P. Baker, had ascended the mountain to a height of 6,500 feet before cloud forced them to return, and during this climb they apparently noticed no premonitory signs of the activity that ensued.* When the eruption began, these two observers were in Mangatepopo Hut, which stands a little more than two miles in a direct line from the crater, opposite and 2,300 feet below the lowest point of its rim.

The eruption did not begin very noisily; some crackling sounds were heard at 1.30 a.m., but it was not until 2.30 a.m. that it was realised that the mountain was in eruption, at which time a red glow could be seen at the summit and boulders were bounding down the slopes. After 9.30 a.m. a clear view of the volcano was obtained and a series of what appear to have been hot avalances was seen to descend the slopes of the cone below the lowest part of the main crater rim. Mr. Bates took a photograph (which he has kindly permitted me to reproduce as Plate 70, fig. 1) of one of these awe-inspiring discharges as it plunged down the slope of the volcano.

The fact that the avalanche material came to rest immediately at the foot of the cone shows that its main propulsive force was gravity rather than explosion of the avalanche particles themselves, so that it must be classed as a glowing avalanche in the usage of Williams (1941, p. 380), rather than as a *nuée ardente*.

Later investigation showed that hot sand and blocks of lava, presumably from such avalanches, covered a sector which was estimated at 350 yards across, on older blocky lavas at the north-west base of Ngauruhoe cone, but the most considerable accumulation was a debris fan about 38,000 square yards in area on the lavas of the floor of Mangatepopo Valley directly below the tip of the later lava-flow. Very large blocks of hot lava were embedded in the sand, and probably many of them formed part of the avalanches; before the products of these avalanches were seen, however, many lava masses tumbling forward from the advancing flow must have added to the original heap of debris, for this process was going on actively when the area was first visited. Subsequently some of the large blocks on the fan spalled down into small pieces as they cooled, but many remain.

---

* This account is condensed from that written at the time by Messrs. Bates and Baker in the Mangatepopo Hut Visitors' Book. Mr. J. Healy, of the N.Z. Geological Survey, has, however, kindly allowed me to see a later report by Mr. Bates, wherein it is recorded that faint mutterings, as of distant thunder, were briefly heard during this ascent.

This fan-shaped mass of sand and lava blocks below the tip of the lava-flow retained its heat for a considerable time. Small "rootless" fumaroles were still steaming and actively depositing sulphur late in April, while in the middle of May at an air temperature of 54° F. a thermometer laid on the sand registered 92° F., while at a depth of three inches the temperature was 122° F.

After 1 p.m. on February 9 the volcano was not under close observation until between 6.00 and 7.00 p.m., when Mr. S. J. Blackmore, of Rotorua, circled over the mountain in an aircraft and took an excellent series of photographs of the crater. These photographs reveal that, at this time, the western sub-crater was filled to within a few tens of feet of its western (outer) lip by a tholoid or plug of lava, the surface of which was gently domed (plate 71, fig. 2). The emission of volcanic gases was taking place very largely from a single vent in the eastern part of the tholoid, more or less above the site of a conelet that had existed in the western sub-crater for a number of years prior to the recent activity (see for example Cotton, 1944, fig. 111, p. 227), while the north-north-west crater was quite inactive. The tholoid seems to have been quite similar to that which rose in the crater of Ruapehu during 1945 (Reed, 1946, Oliver, 1946, Cotton, 1946), and which was examined at close quarters by Oliver.

Some time between 7 p.m. on February 9 and midnight on Thursday, February 10 the rising lava spilled over the north-west lip of the crater and began to descend the side of the cone as a blocky lava-flow. During almost the whole of Thursday the volcano was obscured by cloud, but by midnight the lava-flow was brilliantly visible from a point some 20 miles north-west of the mountain, and already extended well down its flank. It is, of course, difficult to judge, but possibly the lava had by then reached the foot of the ash-cone proper. At this point the flow changed its direction of advance from N.W. by W. to a little N. of N.W., and by noon on Friday, February 11, the lava front had moved forward a quarter of a mile from this bend, over a sloping shelf of older lavas fringing the north-west base of the cone. During this period of 12 hours the lava had advanced probably 600 yards, an average rate of 50 yards an hour. The average slope over this part of its path is about 1 in $2\frac{1}{4}$, but the initial deflection of the flow took place by a side-slip on a much steeper grade. Between 3 p.m. on February 11 and 9 a.m. on the 12th it advanced only about 200 or 250 yards and not many hours later movement ceased, the flow having attained a length of nearly 2,000 yards along the slope, with variation from 50yds. to 150yds. in width, and having a volume of the order of $\frac{3}{4}$ million cubic yards (see map, plate 74).

The flow progressed by the crumbling forward of the steep terminal face under the pressure of rock behind, to the accompaniment of a continual clattering noise. By the afternoon of Friday the blocks that formed the surface of the flow were black, bright red lava showing only in the chinks, but sometimes white-hot rock was disclosed by the tumbling forward of large masses of rock from the terminal face. These rolling rock masses gouged out a channel in the poorly consolidated materials in front of the flow and played a part in defining the course which it subsequently followed. The andesitic lava was quite rigid under the hammer at dull red heat, and the brittleness of the hot blocks in general was a striking characteristic.

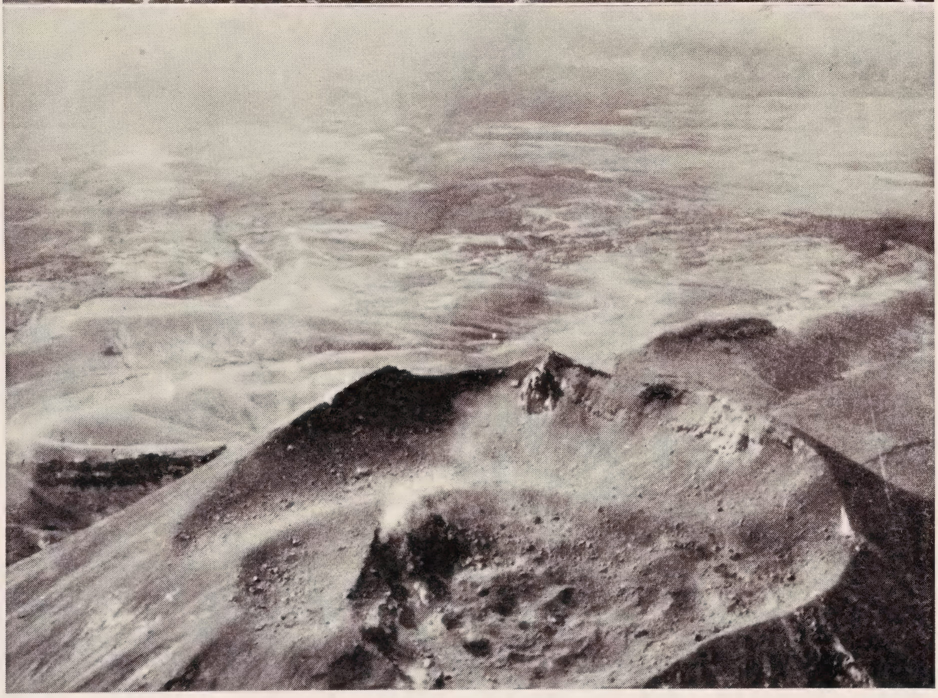


Fig. 1. General view of the lava flow with the fan of avalanche debris below its tip.
Photo: M. H. Battey.

Fig. 2. Air-view of the crater in early March, at the end of the eruption.
Photo: Photo News Ltd.

Levees or "moraines" of piled up lava blocks, such as are commonly formed at the margins of blocky flows, were well developed along the whole length of the flow. In addition, there was a conspicuous median dark zone which appeared to stand as a ridge above the general surface of the flow. As can be seen from plate 70, fig. 2, rolling blocks on the flow were guided down the two gutters between this median ridge and the marginal levees. (It may be mentioned that this dark central zone was visible from a distance of 20 miles on the night of February 10-11, when the main part of the flow glowed much more brightly than on the succeeding night, and must have been moving very actively.) The marginal levees are readily explained as the result of stranding of cooled blocks along the edges of the lava stream, but the reason for the presence of the median ridge is not obvious. Perhaps the flow broke through the crater rim in two places and actually descended the cone as a twin stream, the ridge in the centre representing the junction between these two lines of flow. As may be seen in plate 70, fig 2, the median ridge extended up to the very lip of the crater, while a photograph taken by

Text fig. 2. The north-west crater rim before and after the emergence of the lava flow. Drawn from photographs by Mr. S. J. Blackmore, Rotorua.

Mr. Blackmore on February 13 shows that the lava flow crosses the crater lip in two trough-like passes, with the uppermost end of the median ridge standing between them where, before the emission of lava, there was a slight rise in the middle of the low portion of the crater rim. If the original outbreak occurred in two places the two separate, though contiguous, lava-tongues would be likely to persist as a result of the channelling action, mentioned above, of boulders from each tongue. During the cooling of the flow the lava blocks spalled into small fragments, and by May the median ridge, and the whole upper part of the flow, was becoming ill-defined (plate 73, fig. 1.).

A comparison of two of Mr. Blackmore's photographs taken on February 9 and February 13 from more or less the same position discloses that the lip of the crater was lowered considerably by collapse under the pressure of lava at the time when outflow occurred (see Text fig. 2). This breaking down of the outer crater rim has always seemed a necessary postulate in envisaging the escape of the lava on to the external slopes of the cone, since the testimony of all observers in recent years is that, before the eruption, the eastern rim of the active sub-crater was somewhat lower than that on the west where the escape of lava actually took place. There is nothing to suggest, however, that the avalanches witnessed by Messrs. Bates and Baker on the morning of February 9 were part of this process. Mr. Blackmore's photographs taken on the evening of that day indicate that collapse had not then begun, while most of the material deposited by the avalanches gave every evidence of being of juvenile origin.

During the "lava phase" of the eruption (the phases that Cotton (1946) distinguished at Ruapehu are apt to the present case) very little ash was emitted. The explosions in the vent ejected mainly coarse pyroclastic material. Blackmore's photographs suggest by the light colour of the eruptive cloud that this was also the case during the growth of the tholoid. On February 11 the gas cloud was quite white, having merely a faint yellowish tinge in comparison with ordinary cumulus clouds (see plate 70, fig. 2). A gigantic steady panting sound testified to more or less continuous gas emission at this time. Occasional lulls of three or four minutes' duration indicated temporary blockage of the vent which was relieved by a heavier explosion, sometimes sharp and sometimes deep-toned, followed by a resumption of the rhythmical discharge of gases. Although showers of large hot blocks were being ejected from the crater, the production of ash was quite subordinate.

The lava phase was succeeded, as at Ruapehu, by an ash phase, during which voluminous and spectacular ash-clouds were erupted by intermittent explosion. This form of activity continued with diminishing intensity until the end of February, when the eruption may be said to have ceased.

The tholoid and the lava flow derived from it may perhaps have represented a relatively cool magma-product forced up by gas-pressure developed in the magma below, capable of a limited amount of flow, but too viscous to be shattered by gas-pressure due to expulsion of its own volatiles (cf. Cotton, 1944, Ch. XI, etc.). After the outflow of lava, hotter, less viscous material below exploded under reduced pressure and gave rise to the ash phase.

Photographs (for example plate 73, fig. 2) taken from the air in the early days of March, disclosed that the fragmental material of this last phase had filled up the active sub-crater and the eastern part of the main crater, so that the area enclosed by the main crater rim appeared more or less level. There remained, however, a steep slope on the north side of the active sub-crater, between it and the north-north-west sub-crater, while the latter, though still quite distinct, had been partly filled with rubble. The same state of affairs was found to exist when the crater was visited on May 18. The rubble in the active sub-crater was steaming in places, but the chief source of steam was the steep face on the northern side of the sub-crater. The north-north-west sub-crater was now only about 25 feet deep (it was 90 feet deep in 1928, when Grange and Hurst mapped it) and was quite inactive. An actively-steaming fissure could be traced along the rim of the steep north side of the active sub-crater, and Mr. C. Christophers, who climbed the volcano on the following day under better weather conditions, tells me that similarly active fissures margined the active sub-crater on the east and south sides also. The high cliffs on the north-east side of the main crater rim were also steaming strongly on May 18. Since then, there have been occasional reports of small steam clouds above the volcano, while visitors to the mountain have noted a certain amount of rubble on the fresh snow near the summit, indicating that there have been mild explosions. It seems likely that by this means, and perhaps also by the breaking away of its walls along the encircling fissures, the rubble-choked west sub-crater will gradually be deepened for a time, as it resumes the course of minor variations in aspect which have have gone on since the later part of last century.

Petrography of the 1949 lava

Thomas (1887, p. 308) described as augite-andesites a number of rocks collected at Ngauruhoe by Cussen, including one from the supposed 1869 lava flow. The presence of hypersthene is not recorded. He remarks that before the Tarawera eruption of the previous year the presence of basic rocks in the Taupo volcanic zone was unknown.

Speight (1908) described in general terms the rocks of Tongariro National Park, including those of Ngauruhoe. He recorded the presence of hypersthene in all the lavas, and of small amounts of olivine in some of the later flows which, he remarked, have a basaltic aspect, but are hypersthene-andesites.

Grange, Williamson and Hurst, on their maps of the volcanoes, made between 1928 and 1930, distinguished a number of basaltic lava flows in the area west of Ngauruhoe, but unfortunately petrographic details have not been published. The lavas of Ngauruhoe itself are mapped as andesites.

The rock forming the new lava flow is a glassy hypersthene-augite-andesite which does not differ in any important way from those forming the other Recent flows in the upper part of Mangatepopo Valley.

Its texture is hyalopilitic. The microlitic glass of the groundmass, which is densely crowded with globulites and belonites, together with the tiny round vesicles (.025-.075 mm.) scattered through it, makes up nearly 73% of the rock.

Plagioclase crystals form 17½% and range in size from well-shaped crystals 1.3 mm. long to microlites .01 mm. in length. The larger crystals are strongly zoned, the composition of their material ranging from An_{65} in the central parts to An_{39} in the outer zones. Often they contain zonally arranged inclusions of glass.

A little more than 8% of pyroxene is present and comprises hypersthene and clinopyroxene. Their relative proportions were not accurately determined in making the micrometric analysis, but hypersthene seems to be more plentiful than clinopyroxene. The hypersthene is weakly but distinctly pleochroic in pale brown and very pale green. The clinopyroxene is almost colourless but has a very faint yellowish tinge. In it the optic axial plane is parallel to 010 and the angle Z to c = 44°. The isogyre in section normal to an optic axis is well-curved and suggests an optic axial angle of about 45°. If this is so, the mineral lies somewhere about the dividing-line between augite and sub-calcic augite (Benson, 1944, Table ix, p. 112). In some cases hypersthene encloses remnants of augite crystals, while in others a strip of augite lies along each side of a lath of hypersthene, suggesting nothing so much as occupation by hypersthene of the central part of a twinned augite crystal.

Occasional crystals of olivine may be found, obviously much out of sympathy with their environment and surrounded by reaction rims of hypersthene and little digitate masses of iron ore.

The 1949 lava is very rich in inclusions. Remnants of these are to be found in almost every thin section and they occupied 1.57% of the micrometric traverses run. Although no special study of these has been made, a few notes may not be out of place.

Speight (1908, p. 8) noticed that "inclusions of what is apparently a partially fused rhyolite frequently occur in the lava flows of Ngauruhoe and Ruapehu" and thought that this, if confirmed, might afford proof of the existence of rhyolite below the volcanoes. Grange and Williamson (1930, p. 11) found, as inclusions in lava flows, fragments of greywacke and argillite such as build the Kaimanawa Ranges east of the volcanoes and Taurewa Mountain to the north-west.

One of the larger inclusions of the 1949 flow consists of patches of quartz mosaic (with grains up to .85 mm. across) in a matrix of lath-shaped crystals of wollastonite together with some granular diopside. This may, perhaps, represent the result of alteration of a sandy limestone from underlying beds of the mid- and upper Tertiary sequence, the nearest outcrops of which are in deep gorges 8 or 9 miles north-west of the volcano and around the flanks of Hauhangatahi, 9 miles to the west-south-west. There is limestone in this latter area.

The smaller inclusions, a few of which appear in most thin sections, are in many cases largely made up of little tablets of feldspar about .07 mm. long, varying in composition from basic andesine to medium labradorite in different cases. Little angular patches of glass crowded with fascicles of margarites occur interstially. There are also ill-formed and corroded crystals of hypersthene (up to 0.25 mm. in length in one example), and ovoid patches of densely- crowded magnetite granules, resulting from the destruction of some ferro-magnesian mineral which, on the evidence of one inclusion, *may* be hypersthene. The origin of these inclusions is uncertain. The absence of quartz seems to negative the possibility of ther derivation from either greywacke or ignimbrite.

Acknowledgments: I wish to express my thanks to Miss M. Hurrey and Mr. A. P. Mason for their cheerful assistance (in spite of wretched weather) in mapping the new lava flow; to Mr. R. Cooper and Mr. L. R. Allen for their help in the field; and to Miss Pirie, who drew the figures.

REFERENCES.

BENSON, W. N., 1944. The basic igneous rocks of eastern Otago and their tectonic environment. Pt. IV B. *Trans. Roy. Soc. N.Z., 74*, pp. 71-123.

BIDWILL, J. C., 1841. *Rambles in New Zealand.* London.

COTTON, C. A., 1946. The 1945 Eruption of Ruapehu (New Zealand). *Geogr. Journ., 107*, 140-143.

CUSSEN, Lawrence, 1891. Report on the topographical survey of the Tongariro Mountains.
Report of the Survey Department for the year 1890-91: Appendix No. 3, pp. 36-38.

GRANGE, L. I., 1928. Eruption of Ngauruhoe, March, 1928. *N.Z. Journ. Sci. & Techn., 10*, pp. 143-147.

GRANGE, L. I., & HURST, J., 1929. Tongariro Subdivision. *23rd Ann. Rept. of the Geological Survey Office, 1928-9*, pp. 5-8.

GRANGE, L. I., & WILLIAMSON, J. H., 1930. Tongariro Subdivision. *24th Ann. Rept. of the Geological Survey Branch, 1929-30*, pp. 10-13.

HECTOR, J., 1886. Presidential Address. *Trans. N.Z. Inst., 19*, pp. 461-470 (1887).

HILL, H., 1891a. Ruapehu and Ngauruhoe. *Trans. N.Z. Inst., 24*, pp. 603-625.

HILL, H., 1891b. Tongariro, Ngauruhoe, and Ruapehu as volcanic cones. *Trans. Australasian Assoc. Adv. Sci., 3*, pp. 162-172.

MARSHALL, P., 1908. Crater of Ngauruhoe. *Trans. N.Z. Inst., 41*, pp. 102-103, pls. 5-7 (1909).

MARSHALL, P., 1934. Geology of the [Tongariro National] Park. *Ann. Rept. on Public Domains, etc.: Dept. Lands & Survey;* App., pp. 3-5. Parl. Paper C-10.

OLIVER, R. L., 1945. Further activity of Mt. Ruapehu, May-July, 1945. *N.Z. Journ. Sci. & Techn., 27*, pp. 24B-32B.

REED, J. J., 1945. Activity at Ruapehu, March-April, 1945. *N.Z. Journ. Sci. & Techn., 27*, pp. 17B-23B.

SPEIGHT, R., 1908. Geology of Tongariro National Park: in Dept. of Lands: *Report on a botanical survey of the Tongariro National Park.* Parl. Paper, C-11, by L. Cockayne, pp. 7-13.

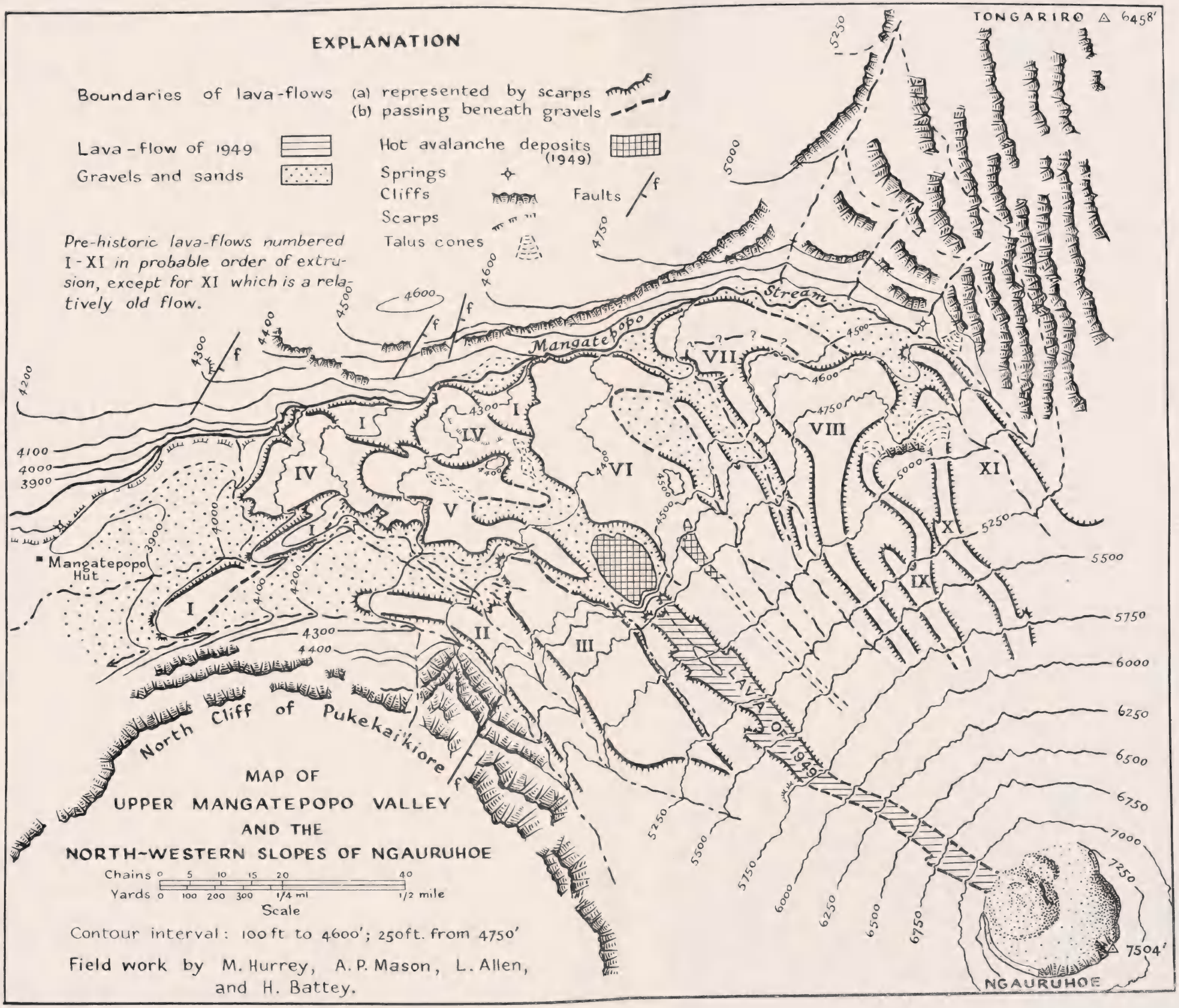
THOMAS, A. P. W., 1887. Notes on the volcanic rocks of the Taupo district and King Country. *Trans. N.Z. Inst., 20*, pp. 306-311 (1888).

THOMAS, A. P. W., 1888. Notes on the geology of Tongariro and the Taupo district. *Trans. N.Z. Inst., 21*, pp. 338-353 (1889).

THOMSON, J. ALLAN, 1926. Volcanoes of the New Zealand-Tonga volcanic zone. A record of eruptions. *N.Z. Journ. Sci. & Techn., 8*, pp. 354-371.

TURNER, E. PHILLIPS, 1911. A short account of a visit to Ngauruhoe and Tongariro volcanoes. *Rept. Dept. Lands for the year 1910-11;* App. VI, pp. 34-35.

WILLIAMS, HOWEL, 1941. Volcanology: in *Geology, 1888-1938*, Geol. Soc. Amer., 50th Anniv. Vol., pp. 367-390.


EXPLANATION
Boundaries of lava-flows (a) represented by scarps
(b) passing beneath gravels
Lava-flow of 1949
Gravels and sands
Hot avalanche deposits (1949)
Springs
Cliffs
Faults
Scarps
Talus cones
Pre-historic lava-flows numbered I-XI in probable order of extrusion, except for XI which is a relatively old flow.
TONGARIRO 6458′
Mangatepopo Stream
Mangatepopo Hut
North Cliff of Pukekaikiore
LAVA OF 1949
NGAURUHOE 7504′
MAP OF UPPER MANGATEPOPO VALLEY AND THE NORTH-WESTERN SLOPES OF NGAURUHOE
Chains 0 5 10 15 20 40
Yards 0 100 200 300 1/4 ml 1/2 mile
Scale
Contour interval: 100 ft to 4600′; 250 ft. from 4750′
Field work by M. Hurrey, A. P. Mason, L. Allen, and H. Battey.